CLAIMS

1. A method for timing misalignment determination in a radio receiver, comprising the steps of:

estimating and correcting a frequency offset and establishing a time reference wherein the boundary between the short- and long-preamble is sufficient;

constructing a real signal from a complex time-domain signal associated with said short preamble;

extracting an n-sample sequence from a portion of said short preamble to obtain a plurality of equidistant equal amplitude frequency peaks; and

determining a timing offset estimate by inspecting the relative phases of said plurality of equidistant equal amplitude frequency peaks;

wherein, data encoded in said received radio signal may thereafter be demodulated.

2. The method of Claim 1, wherein:

the step of constructing includes in-phase and quadrature-phase sampling of said received radio signal to obtain a real part and an imaginary part;

wherein real and imaginary parts are similar to one another except for a fixed time-skew between them.

3. The method of Claim 2, wherein:

the step of constructing includes a simple addition of said real and imaginary parts to obtain said real signal.

4. The method of Claim 1, wherein:

the step of determining is such that phase of a set of three frequency peaks Φ_1, Φ_2 and Φ_3 is assumed to vary with timing misalignment

between $\Delta(t)$ and $\delta(t)$, and an intra-baud timing offset τ can be derived from Φ_1, Φ_2 and Φ_3, wherein, a received signal can be represented by,

$$\begin{aligned}\Psi(t) &= \Phi_1(t) + 2\Phi_2(t) + \Phi_3(t) \\ &= \frac{\pi}{4}\left(1+\frac{t}{T_s}\right) + 2\frac{\pi}{4}\left(1+2\frac{t}{T_s}\right) + \frac{3\pi}{4}\left(-1+\frac{t}{T_s}\right) \\ &= 2\pi\frac{t}{T_s}\end{aligned}$$

and, $\Psi = (X_8 P_1)(X_{16} P_2)^2 (X_{24} P_3)$, where X_k and P_n respectively designate 64-point fast Fourier transform frequency components and the phase correcting coefficients needed compensate for phase offset errors cause by a misalignment between $\Delta(t)$ and $\delta(t)$, and the timing misalignment τ is expressed as a fraction of T_s, and is $\tau = \dfrac{\Psi}{\pi}$.

5. The method of Claim 1, wherein:

the step of determining computes a 64-point fast Fourier transform rather than a three-point discrete Fourier transform.

6. A method for timing misalignment determination in a radio receiver, comprising the steps of:

determining a boundary between a short preamble and a long preamble in a received radio signal;

linearly combining samples of two long sequences from said long preamble to obtain an idealized sequence of samples that best approaches under a certain criterion an ideal sequence of samples;

computing a normalized dot product of said idealized sequence of samples and an ideal on-baud sampled sequence to obtain a magnitude estimate of any timing misalignment; and

computing a dot product of said idealized sequence of samples and the time derivative of the ideal on-baud sampled sequence mentioned above to obtain a sign of any timing misalignment;

wherein, data encoded in said received radio signal may thereafter be corrected for timing misalignment and then demodulated.

7. The method of Claim 6, wherein the steps of linearly combining and computing can use cost function can be used, and mathematically described by,

$$
\begin{aligned}
C(\alpha_1,\alpha_2) &= \left\| \vec{R}_{on} - \begin{bmatrix} \vec{X}_1 & \vec{X}_2 \end{bmatrix} \begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix} \right\|^2 \\
&= \left(\vec{R}_{on} - \begin{bmatrix} \vec{X}_1 & \vec{X}_2 \end{bmatrix} \begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix} \right)^H \left(\vec{R}_{on} - \begin{bmatrix} \vec{X}_1 & \vec{X}_2 \end{bmatrix} \begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix} \right) \\
&= \left(\vec{R}_{on}^H - \alpha_1^* \vec{X}_1^H - \alpha_2^* \vec{X}_2^H \right)\left(\vec{R}_{on} - \alpha_1 \vec{X}_1 - \alpha_2 \vec{X}_2 \right) \\
&= \left\| \vec{R}_{on} \right\|^2 - 2\operatorname{Re}\left(\alpha_1^* \vec{X}_1^H \vec{R}_{on} \right) - 2\operatorname{Re}\left(\alpha_2^* \vec{X}_2^H \vec{R}_{on} \right) + 2\operatorname{Re}\left(\alpha_1^* \alpha_2 \vec{X}_1^H \vec{X}_2 \right) + |\alpha_1|^2 \left\| \vec{X}_1 \right\|^2 + |\alpha_2|^2 \left\| \vec{X}_2 \right\|^2
\end{aligned}
$$

where,

$\vec{X}_1 = \vec{C}_1 \cdot \times \vec{R}_{off} + \vec{N}_1$ is the first sequence of the long preamble,

$\vec{X}_2 = \vec{C}_2 \cdot \times \vec{R}_{off} + \vec{N}_2$ is the second one,

$\vec{R}_{on}$ and $\vec{R}_{off}$ respectively designate the on - baud and off - baud sampled reference sequence,

α_1 and α_2 are the weighting coefficients,

$$
\vec{C}_1 = \left| \begin{matrix} e^{j\varphi_1} \\ e^{j2\pi\frac{v}{F_s}+j\varphi_1} \\ \vdots \\ e^{j2\pi\frac{v}{F_s}63+j\varphi_1} \end{matrix} \right. ,
$$

$$
\vec{C}_2 = \left| \begin{matrix} e^{j\varphi_2} \\ e^{j2\pi\frac{v}{F_s}+j\varphi_2} \\ \vdots \\ e^{j2\pi\frac{v}{F_s}63+j\varphi_2} \end{matrix} \right. , and
$$

v designates the frequency offset.

and, minimizing $C(\alpha_1,\alpha_2)$ with respect to α_1 and α_2 yields,

$$\frac{\partial C}{\partial \alpha_1} = -\vec{R}_{on}^H \vec{X}_1 + \alpha_2^* \vec{X}_2^H \vec{X}_1 + \alpha_1^* \left\|\vec{X}_1\right\|^2$$
$$= -\sum_{n=0}^{63} R_{on}^*(n) R_{off}(n) e^{j2\pi\frac{v}{F_s}n + j\varphi_1} + \alpha_2^* e^{j(\varphi_1-\varphi_2)} \sum_{n=0}^{63} \left|R_{off}(n)\right|^2 + \alpha_1^* \left(\left\|\vec{R}_{off}\right\|^2 + \sigma_N^2\right)$$
$$= -e^{j\varphi_1} P + \alpha_1^* \left(S + \sigma_N^2\right) + \alpha_2^* e^{j(\varphi_1-\varphi_2)} S$$

$$\frac{\partial C}{\partial \alpha_2} = -\vec{R}_{on}^H \vec{X}_2 + \alpha_1^* \vec{X}_1^H \vec{X}_2 + \alpha_2^* \left\|\vec{X}_2\right\|^2$$
$$= -\sum_{n=0}^{63} R_{on}^*(n) R_{off}(n) e^{j2\pi\frac{v}{F_s}n + j\varphi_2} + \alpha_1^* e^{j(\varphi_2-\varphi_1)} \sum_{n=0}^{63} \left|R_{off}(n)\right|^2 + \alpha_2^* \left(\left\|\vec{R}_{off}\right\|^2 + \sigma_N^2\right)$$
$$= -e^{j\varphi_2} P + \alpha_1^* e^{j(\varphi_2-\varphi_1)} S + \alpha_2^* \left(S + \sigma_N^2\right)$$

with: $\sigma_N^2 = \vec{N}_1^H \vec{N}_1 = \vec{N}_2^H \vec{N}_2$, $S = \sum_{n=0}^{63} \left|R_{off}(n)\right|^2$ and $P = \sum_{n=0}^{63} R_{on}^*(n) R_{off}(n) e^{-j2\pi\frac{v}{F_s}n}$

.

8. The method of Claim 7, wherein the steps of linearly combining and computing assume that $\vec{N}_1^H \vec{N}_2 = \vec{N}_1^H \vec{X}_2 = \vec{N}_2^H \vec{X}_1 = \vec{N}_1^H \vec{R} = \vec{N}_2^H \vec{R} = 0$, although such is not exactly true in reality, and thereby reduces computer processing required; and continuing with,

$$\begin{cases} \dfrac{\partial C}{\partial \alpha_1} = 0 \\ \dfrac{\partial C}{\partial \alpha_2} = 0 \end{cases} \Rightarrow \begin{bmatrix} S + \sigma_N^2 & e^{j(\varphi_1-\varphi_2)} S \\ e^{j(\varphi_2-\varphi_1)} S & S + \sigma_N^2 \end{bmatrix} \begin{bmatrix} \alpha_1^* \\ \alpha_2^* \end{bmatrix} = \begin{bmatrix} e^{j\varphi_1} P \\ e^{j\varphi_2} P \end{bmatrix}$$
$$\Leftrightarrow \begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix} = \frac{1}{\left(S + \sigma_N^2\right)^2 - S^2} \begin{bmatrix} S + \sigma_N^2 & -e^{j(\varphi_2-\varphi_1)} S \\ -e^{j(\varphi_1-\varphi_2)} S & S + \sigma_N^2 \end{bmatrix} \begin{bmatrix} e^{-j\varphi_1} P^* \\ e^{-j\varphi_2} P^* \end{bmatrix}$$
$$\Leftrightarrow \begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix} = \frac{P^*}{2S + \sigma_N^2} \begin{bmatrix} e^{-j\varphi_1} \\ e^{-j\varphi_2} \end{bmatrix}$$

in the absence of any timing misalignment, frequency offset or Gaussian noise, the weighting coefficients are simply, $\begin{bmatrix} \alpha_1 \\ \alpha_2 \end{bmatrix} = \frac{1}{2} \begin{bmatrix} e^{-j\varphi_1} \\ e^{-j\varphi_2} \end{bmatrix}$.

9. The method of Claim 8, wherein the steps of linearly combining and computing produce an $\Gamma(\nu)$ that is real and much greater than $|R_{on}(0)|^2$, and the result is $\angle P_{on}^{\hat{}} \cong -2\pi \frac{\nu}{F_s} 32$ radian, and wherein, P^* is composed of two phase coefficients, a first one (P_{on}^*) centers the frequency offset related phase component around $Z(32)$, and the second one ($P_{\Delta}^{\hat{}}$) contains timing-misalignment information.

10. The method of Claim 9, wherein the steps of linearly combining and computing find $\vec{Z}$, and determine the absolute value and sign of the timing misalignment by computing dot products, as in,

$$\gamma_{\text{value}} = \frac{\left|\vec{Z}^H \vec{R}_{on}\right|}{\left\|\vec{R}_{on}\right\|^2} \frac{\lambda_{\max}}{\lambda_{\max} - \lambda_{\min}}$$

where: $\{\lambda_{\max}, \lambda_{\min}\} = \mathrm{eig}(M^H M)$ with $M = [\vec{X}_1 \quad \vec{X}_2]$, and

$$\gamma_{\text{sign}} = \mathrm{Re}\left(\vec{Z}^H \frac{\partial \vec{R}_{on}}{\partial t}\right) .$$